June 27, 1967

The Technical Session, held in the Adams Room of the Palmer House, Chicago, Illinois, convened at nine o'clock, a.m., Col. DeWolf Schatzel, A. Earl Cullum, Jr., Consulting Engineers, Dallas, Texas, presiding.

CHAIRMAN SCHATZEL: Good morning, ladies and gentlemen.

For the benefit of any of you who do not know where you are or what you are doing here (laughter), let me announce that this is the Tuesday morning Technical Session of the NCTA Convention.

My name is "Dutch" Schatzel, and I have the pleasure of presiding over the meeting this morning, and more particularly of introducing the speakers.

We have a great deal of highly important and interesting information to pass on to you today through our various speakers, so we are going to endeavor to be as brisk as possible and move along rapidly adhering to the schedule as closely as possible.

Our first presentation this morning is a sort of a "double play" actually, for we have two speakers. I am going to introduce the first, who will then introduce the second speaker, after, I understand, some brief remarks.

The subject is one we have all been following with great interest for the past couple of years. The subject is SHORT HAUL MICROWAVE, another means for getting information in large volume from one point to another rather nearby point.

The people who have been doing this represent a joint venture, as I understand it, of the TelePrompTer Corporation and Hughes Aircraft Corporation.

Our first speaker this morning represents Hughes Aircraft Corporation, and is a graduate of the University of Utah, where he also received his Doctorate.

He has had 12 years of very wide experience in microwave developments of all kinds, and at the present time is the Manager of the Microwave Components Department of the Research and Development Division of Hughes Aircraft Company.

It is a great pleasure to introduce Dr. Howard Ozaki (Applause).

DR. HOWARD OZAKI (Hughes Aircraft Company): Thank you very much.

This paper is a joint effort of Mr. Lyle Stokes and myself, and will be presented by Mr. Stokes who is a Senior Scientist in the Research and Development Division of the Hughes Aircraft Company where he is presently Head of the Telecommunications Group Staff.

His past credits include responsibility for the subsystem design for the receiver signal processing, transmitter and television sub-systems for the Surveyor Spacecraft. Before that time he had worked in many missile and electronics radar applications.

More important to us in our department, he was one of the chief instigators and contributors to the AML short haul microwave concept, and he has been working with us since the beginning of the program. What you have seen and are to see is in great part due to his early efforts in this program.

With that, I introduce Mr. Lyle Stokes. (Applause)

MR. LYLE S. STOKES (Senior Scientist, Systems Laboratory, Research and Development Division, Aerospace Group, Hughes Aircraft Company, Culver City, California):

In May 1965, a representative of the TelePrompTer Corporation came to Hughes Aircraft to discuss some of their hopes for the future. It was suggested that there was a need for a particular kind of microwave link, and the discussion continued on as to the possibility of doing something about it.

As a result, I had a call wanting to know if I would like to be involved in the project.

It developed that they desired to transmit 12 channels of television to multiple receivers in a metropolitan area in order to eliminate the necessity for digging up the streets to lay coaxial cable. In addition, they wanted to be able to use such a system for point-to-point operation to satellite cities. There was also involved the possibility of jumping barriers such as rivers and other obstacles that would be very costly in getting around by ordinary means.

I gave it some thought and began to wonder how we were going to do this. I continued thinking about it, and approximately a month later we did get together with the TelePrompTer people, and I asked them what they were going to call this?

They indicated it would be known as the Short Haul Multiple Channel Microwave Link.

As you can readily understand this represents quite a mouthful, and we decided to shorten it and call it AML . . . meaning Amplitude Modulated Link. Several weeks later we had an operating "breakboard" which is shown on the first slide (slide).

This really contains all of the components of the link as we eventually camp up with it. You have the transmitter, which is located in this lower region (indicating), adjacent to the horn.

Our desire was to put complexity into the transmitter and make the receiver simple because we hoped to use a number of them with each transmitter. You can readily see that we achieved that goal.

We invited our division director down to see this, and gave him an opportunity to view all of Los Angeles' television signals coming over, and all of the Los Angeles' frequency modulation station as well. He looked at Channels 2, 4, 5, 9, 11, and 13, and he indicated he thought it was great.

We sent on to the experimental stage. First at X Band, and then at 18 gigahertz.

We chose this, first, because it was not crowded; and second, it was also one that had reasonable losses in terms of weather.

We desired 12 channels, and we have 12 channels now.

We aimed at 57 db overall as the system inter-modulation specification where each inter-modulation product should be at least that far below the peak carrier.

The range of six miles was one which we achieved with a rather low-power transmitter which I will mention later as we move along.

It provided a wide beam so as to cover a large section of the city. The output was equal to the input frequencies. This was important where the eventual signal coming to the home would be in competition with the signal from the TV station itself. We wanted to have them identical so that there would be no beat notes between the two signals. We have achieved that by a phase-lock receiver.

(Slide) Here we see a transmitter block diagram. We have omitted the proprietary lines from this. We really have two transmitters, divided in half, with a line going through that area (indicating).

The klystron is synchronized or phase-locked to a crystal, and that crystal is in the synchronizer. The synchronizer has a signal that also comes to this lower converter (indicating), where a tone is placed between Channels 4 and 5. You will note the 4 megacycle gap, and the tones put into that gap are the ones which we use in the receiver to develop our synchronous receiver local oscillator.

The oscillator, then is coherent with the crystal frequency, or the klystron, as shown here (indicating).

The important step is the converter that shifts the incoming signals to a higher frequency, and from there they filter off into a single side band filter, and to the transmission amplifier.

In the particular case indicated, the RF signals add in space, eliminating any loss you might encounter.

(Slide) The receiver is the sort of elemental structure you would have in a UHF down converter. We are using UHF a little higher in this case. It has an additional feature that you do not find in most UHF converters, namely a phase-lock loop which gets rid of the beat problem that I mentioned earlier.

A pilot tone filter of about one megacycle bandwidth removes all channels of the 4 TV channels and leaves just the pilot tone at a frequency between channel 4 and 5. Then the phase detector compares that tone with the solid state multiplier frequency. This is all done automatically.

(Slide) We have gone through the block diagram. We know the frequency we will operate at, and the next is the question of the parameters.

This (indicating slide) represents a diagram of those parameters.

The required output signal to noise ratio is 45 db peak to RMS, which is an excellent quality TV signal. We have a 12 db receiver noise figure. The receiving antenna has a gain of 44 db which corresponds to a 4-foot dish.

We have for the transmitter chosen to use a 27 db gain antenna which provides a large fan (approximately 15 degrees wide) and two degrees in height for the six mile range.

With higher gain antennas you can well imagine that longer ranges are available.

The design margin of 7 db is to provide for propagation effects such as rain, fog, and snow. With this particular set of parameters you can endure a rain rate of one-half inch per hour, which is called by the weather bureau "heavy rain", and there is still no loss in signal to noise ratio.

(Slide) The next few slides will show the experimental stages.

This is the converter stage.

(Slide) This is the power amplifier.

(Slide) This is our "breadboard" receiver. The antenna remains pretty much the same as in the prototype which we will see in a moment.

(Slide) This shows the inside of the receiver. The output of this unit can feed directly into the home receiver, and the TV signals are available there.

We now had a transmitter-receiver experimental version, and the next thing to do was to conduct experiments with it.

(Slide) We found that, indeed, we could put 12 channels through the system. We determined where the inter-modulation level came out. We found that the transmitter noise figure was suitably low with the type of up-converter and the type of traveling wave tubes we knew we could make.

We had identical input and output signal frequencies because of the pilot tone that had been added.

The next thing we needed to do was to conduct some rain tests. We did them in New York City. These were made over a period of four or five months. The data was analyzed.

This (indicating slide) represents a summary of that data. It turned out about as you would expect in computing weather statistics. Most weather data will state that it rained an inch during a particular day. It may have happened in a minute, or some very short period of time, and this may wipe you out. If it happened all day, it would not bother you.

As far as I know, only one person has done work on short term weather effects and in this instance it is a gentleman by the name of Bussey. This individual has analyzed the statistics for one minute; one hour; and one half-hour. Using the data he had available there for the types of weather and comparing it with weather data we actually observed in New York City, we came up with this curve (indicating), which shows the New York City-Washington, D.C. expected performance.

If you will look at this line (indicating) for 40 db, it indicates that the performance of our system we expect to be 40 db or better except for six hours a year, at a six-mile range. At a four-mile range, for instance, it indicates that signal to noise ratios should be 40 db or better except for about two and a half hours a year.

So, there is a very small time each year when we expect the signal to go down below the 45 db excellent picture quality. These two, three, or four hours, however, will give us a type of "snow" picture in the 20 db range, and it may occur between midnight and three o'clock in the morning, when not too many people will be watching.

With these experimental tests being conducted, Hughes and TelePrompTer embarked in a joint venture called Theta-Com, and decided to build some prototypes.

(Slide) Many of you have seen the receiver in the display. This is the inside of it.

This box is now approximately 14 inches by 9 inches by 2-1/2 inches.

The package is done in a casting. It has a separator down the center, and there is an upper and lower level; and it provides the RF shielding between various portions of the receiver.

This entire unit is shielded with a copper sheet over top and bottom before being hermetically sealed.

It has, as you can see, two wires going in, and this represents a 28-volt DC as required, with the third wire, which is the VHF output, which goes directly into the CATV system.

(Slide) This is the driver unit, the prototype driver unit, that you may have seen in the display. It has two outputs that can be combined into a single output if desired, or can drive two separate amplifiers.

(Slide) One thing that was required for the prototype was a sufficiently high power traveling wave tube. There are none available. Hughes, however, has built a number of traveling wave tubes. In fact, they are presently aboard the Surveyor and other satellites used by NASA. They are aboard the Boeing Lunar Orbiter; the JPL Mariner; and Apollo Spacecraft.

The traveling wave tubes developed have collectively accumulated over 10 years in space without a single failure so far. These traveling wave tubes have also been put in high-power radars with average powers in the order of many hundreds of watts.

So, we would like to have a traveling wave tube that has low noise and high power and operates in the 18 gigahertz band.

We asked what could be done?

As we realize, high power and low noise do not go together.

We, however, designed a tube that was built specifically for high power and low noise. This is the "innards" of that tube. (Slide)

At the far end, at the top of the picture, is the black item which is the electron gun, next is the traveling structure, next the input and output wave guide flanges; the collector heat sink; and at the end it has its own private ion pump to take care of the loose ions that might be floating around.

This TWT has a saturated output of 250 watts.

Actually, you would operate this tube at about one and a half to two watts total output power in order that the IMP be sufficiently low.

There are two of these units, plus the drive unit, plus the receiver unit, which make a complete system. It has, however, several options depending on the type of range required.

(Slide) This is the prototype unit. We have the receiver, the receiver antenna, and they are shown in the next slide (slide), and in this you will recognize the prototype as you have seen it in the display.

This is a completely weatherproofed unit and is suitable for us in any of the various available AML configurations.

(Slide) This shows a transmitter antenna. It is a side view indicating the input flanges and mounting brackets.

(Slide) This shows a front view of the antenna, and here you can see how two antennas are combined into one package. The idea is that each of these sections is driven by a single power amplifier, and here is where the diplexing is done, rather than having a diplexing loss before the antenna structure is encountered.

Those are the antennas, and that is the prototype system.

Right now we have reached the point in the pilot line production where we have a number of receivers; we are working on a number of transmitters; and we are moving along on a system that gives over 100 megacycles of base band capability.

Thank you very much. (Applause)

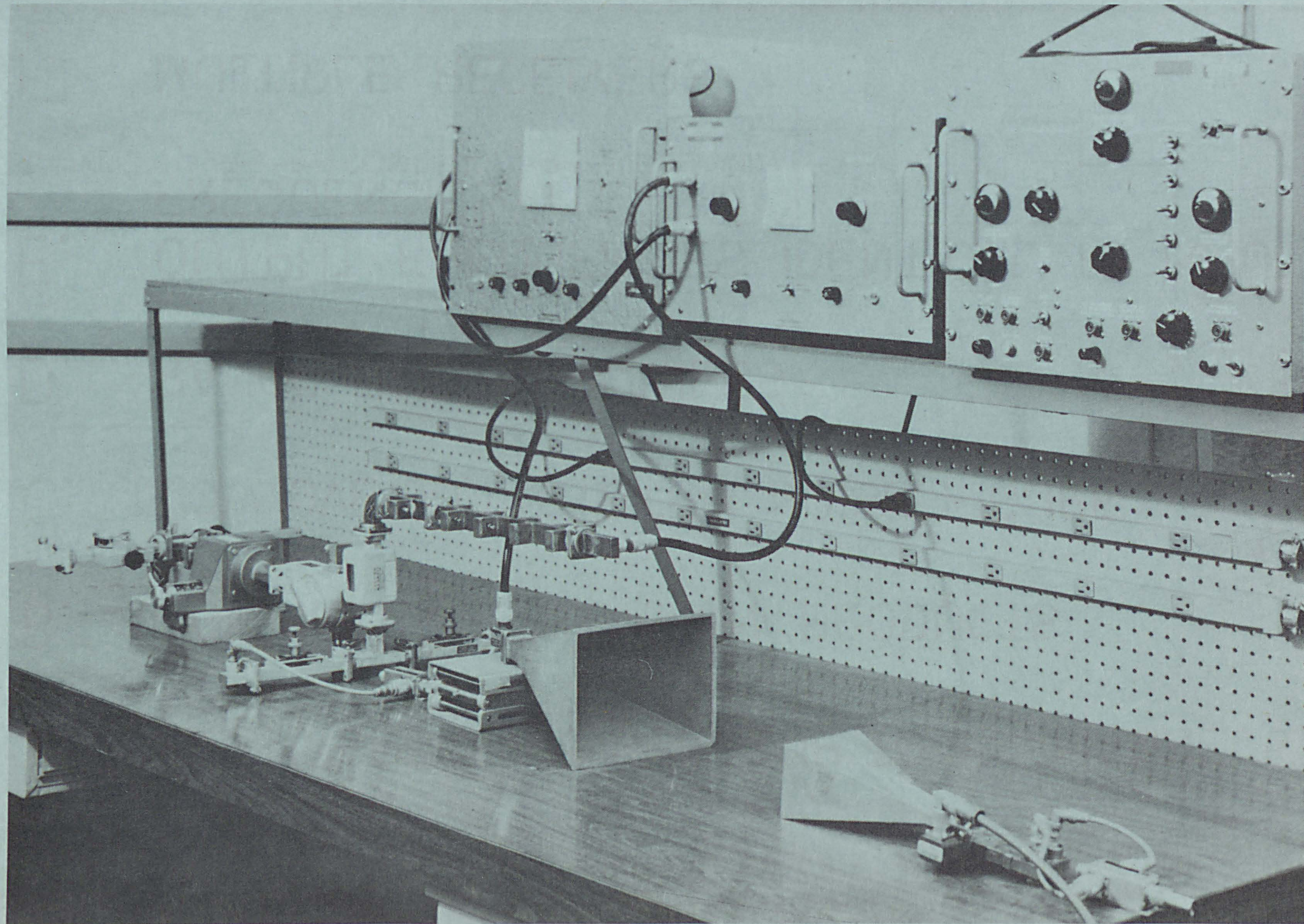


Figure 1 X-band Breadboard of AML system

18 gHz MICROWAVE LINK

A. MULTIPLE CHANNELS (UP TO 12 CHANNELS)

B. LOW INTERMODULATION PRODUCTS

C. LOW OVERALL SYSTEM NOISE FIGURE

D. RANGE UP TO SIX MILES

E. OUTPUT FREQUENCIES IDENTICAL TO INPUT FREQUENCIES

F. MULTIPLE RECEIVERS

Figure 2 AML Overall specificiation

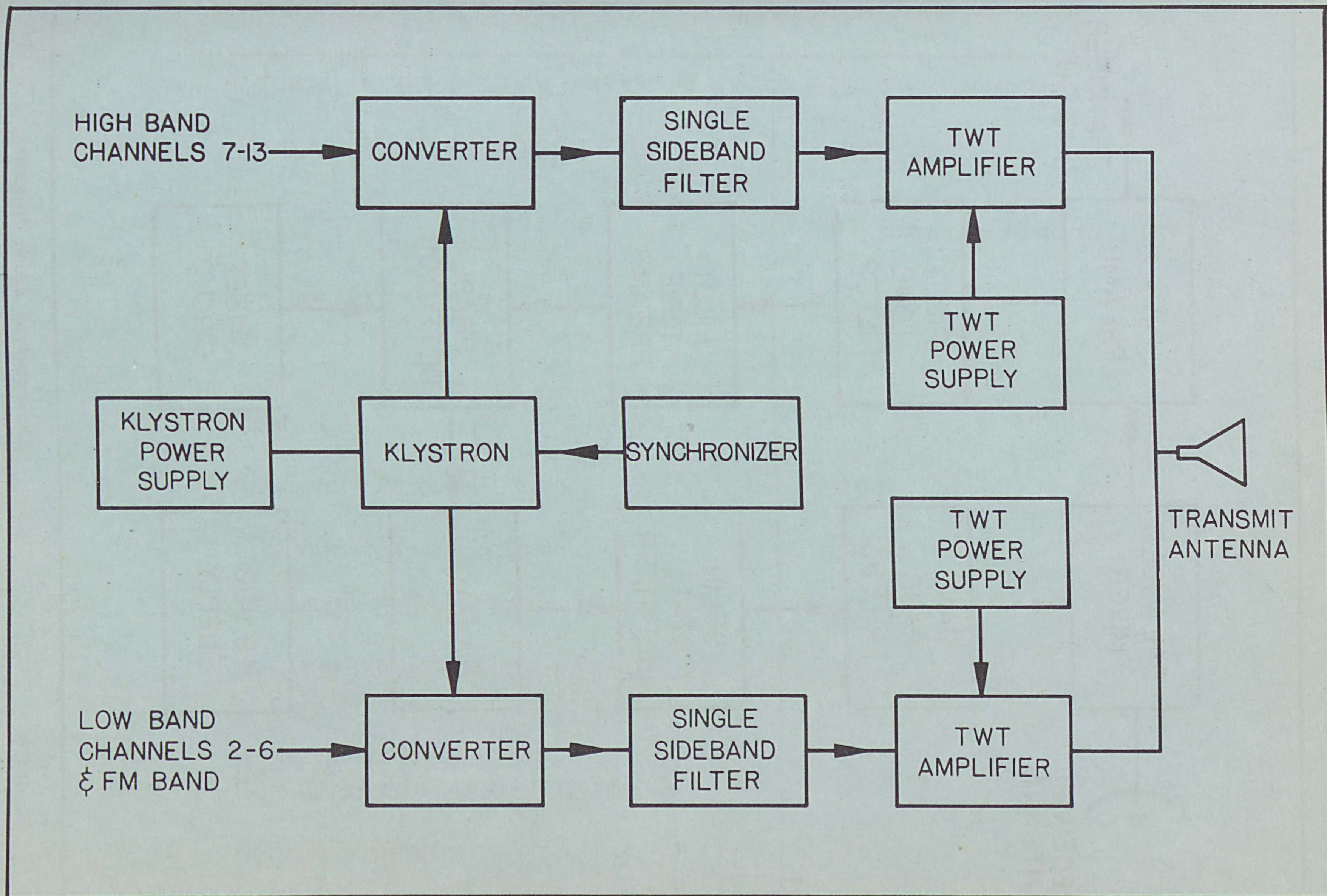


Figure 3 AML transmitter block diagram

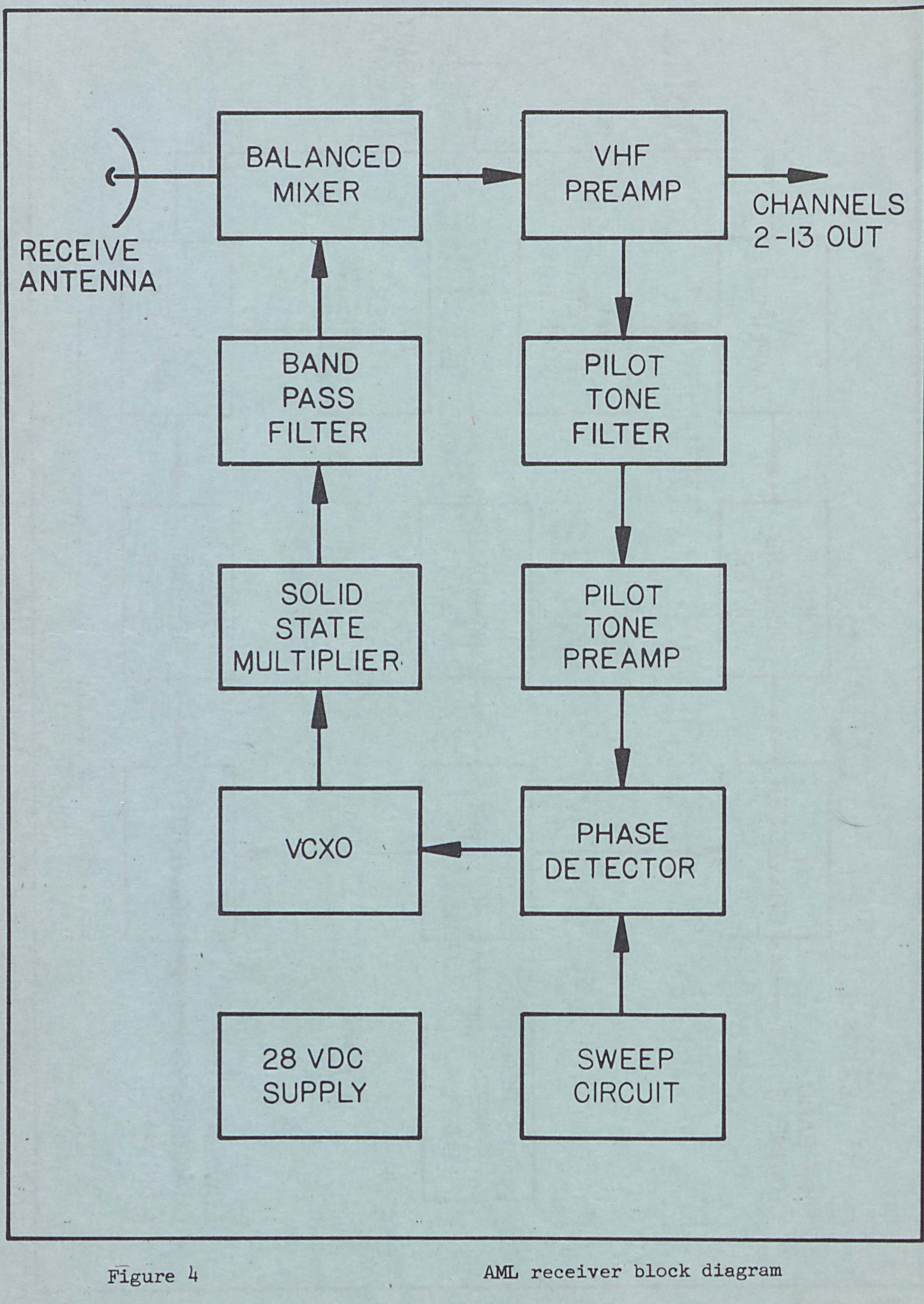


Figure 4 AML receiver block diagram

Figure 5 AML operating parameters

THERMAL NOISE (KTB) DENSITY	−59 dbmv	(−108 dbm)
NOMINAL RECEIVER NOISE FIGURE	12 db	
RECEIVER NOISE DENSITY (PER 4 mc CHANNEL)	−47 dbmv	(−96 dbm)
REQUIRED PEAK SIGNAL TO RMS NOISE RATIO	45 db	
MINIMUM RECEIVED PEAK POWER PER CHANNEL	−2 dbmv	(−51 dbm)
RECEIVER ANTENNA GAIN	−44 db	
PROPAGATION LOSS (6 MILES)	+138 db	
TRANSMITTER ANTENNA GAIN	−27 db	
MINIMUM TRANSMITTER PEAK POWER PER CHANNEL	+65 dbmv	(+16 dbm)
MINIMUM TRANSMITTER PEAK POWER FOR 12 SYNCHRONOUS CHANNELS	+76 dbmv	(+27 dbm)
DESIGN MARGIN	7 db	
TOTAL TRANSMITTER POWER	+83 dbmv	(+34 dbm)

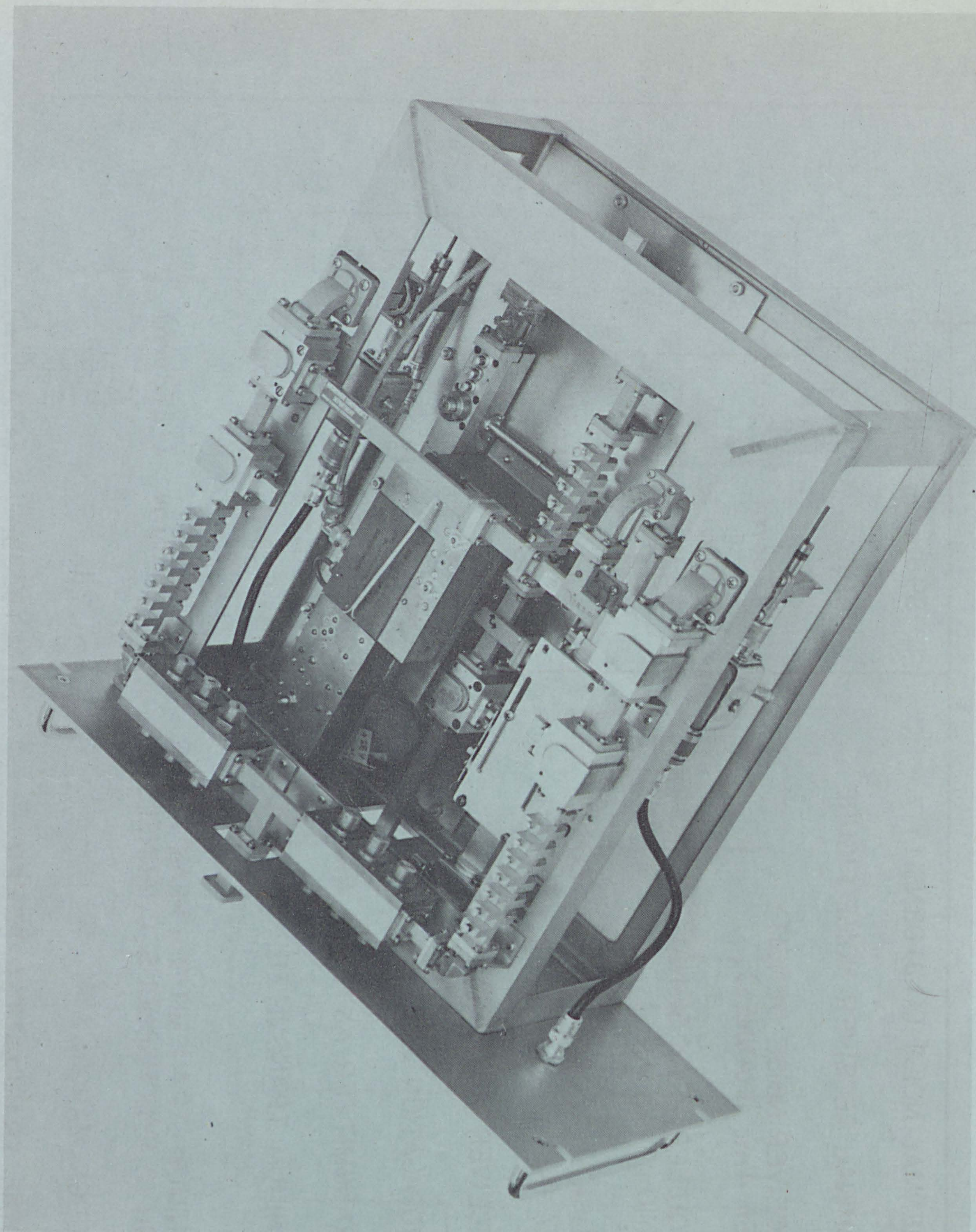


Figure 6 AML experimental model upconverter

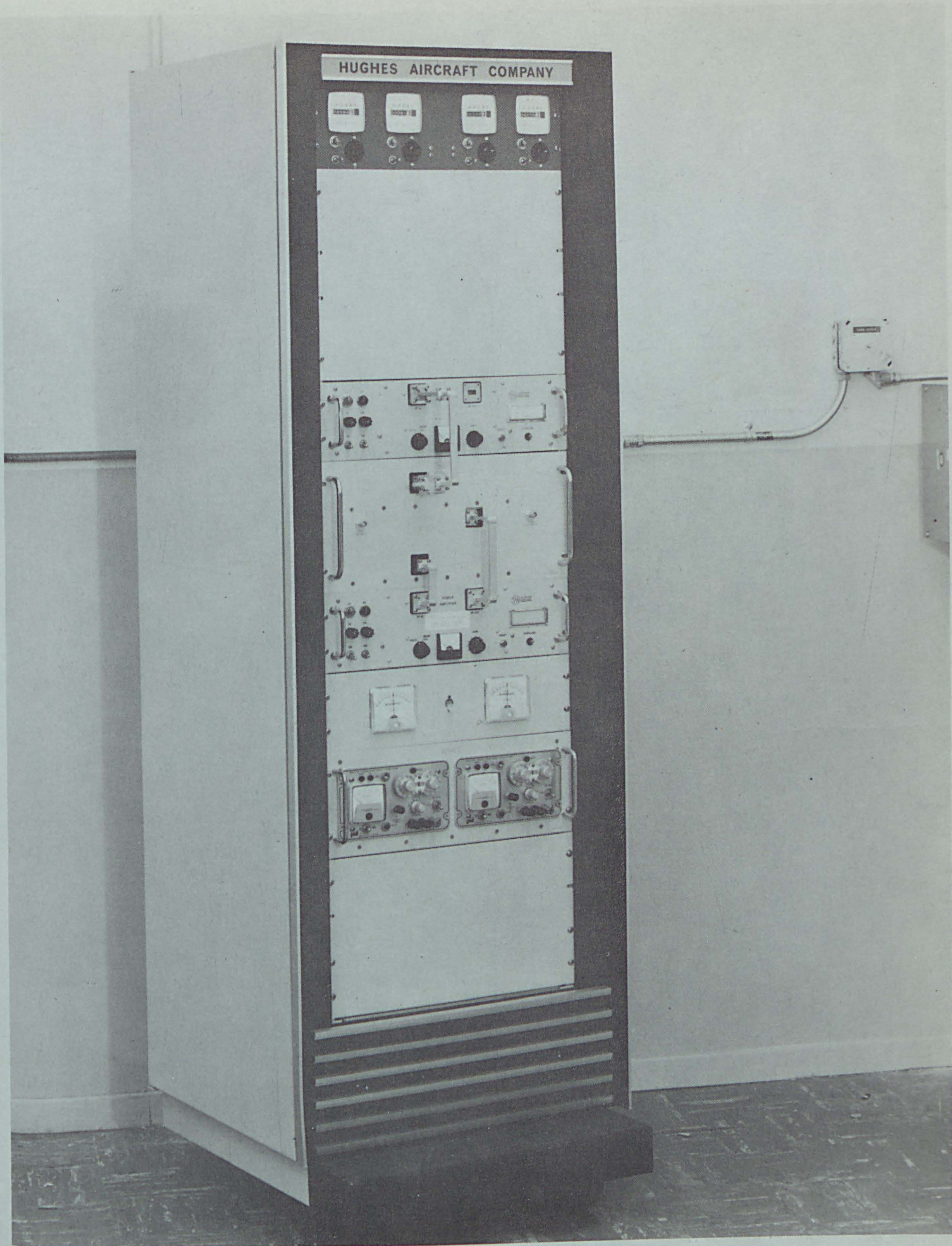


Figure 7 AML Experimental Power Amplifier

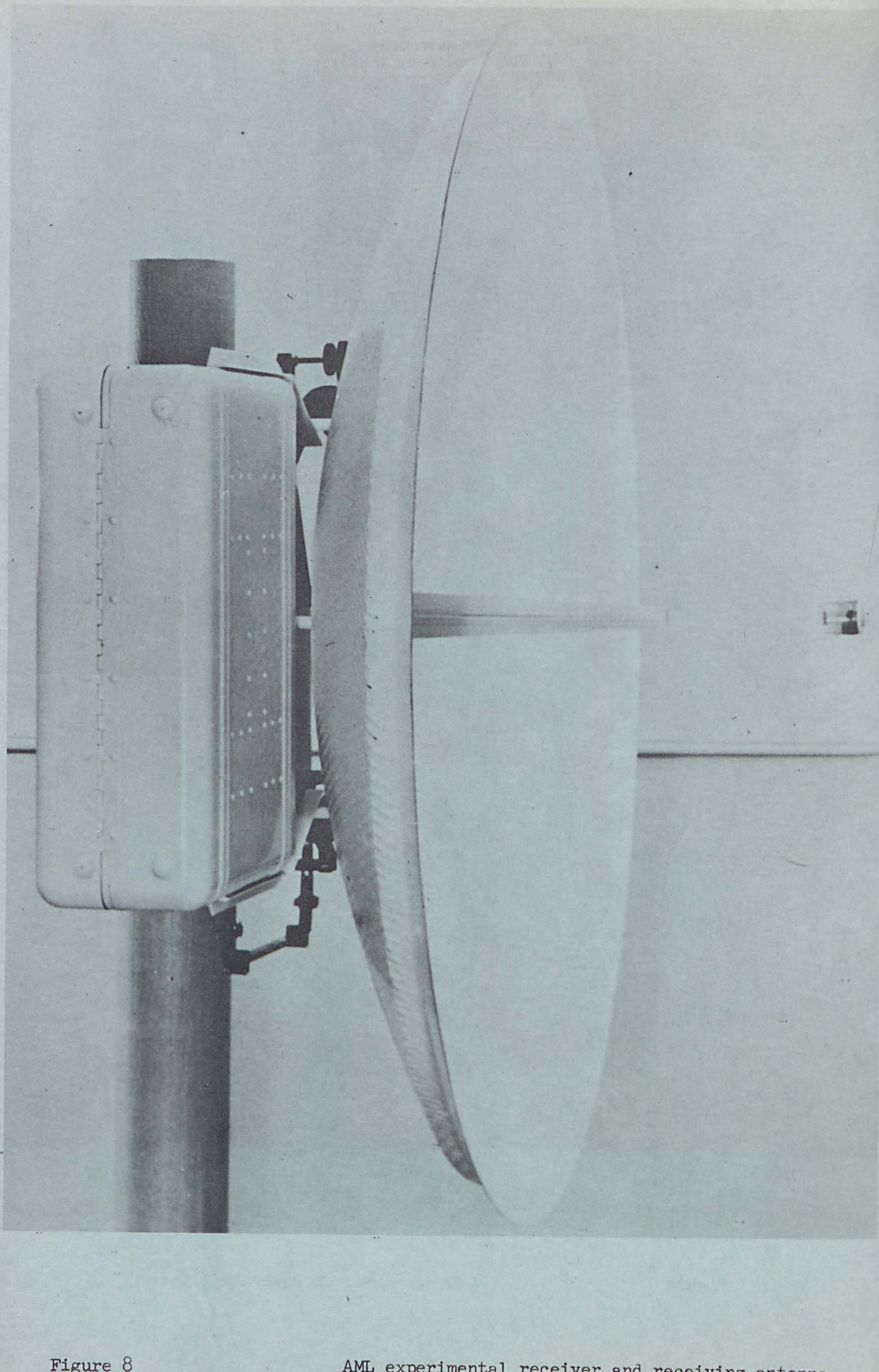


Figure 8 AML experimental receiver and receiving antenna

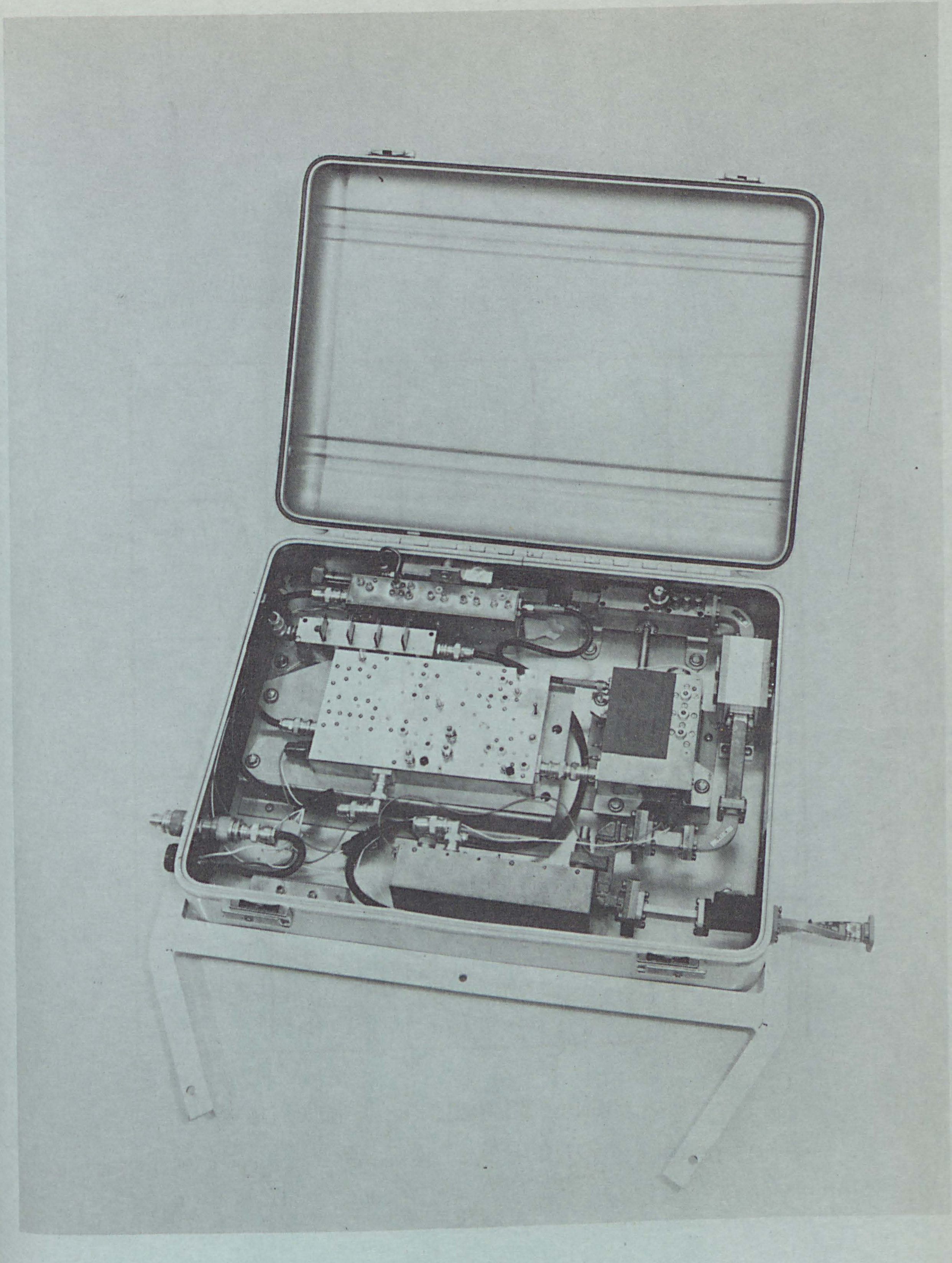
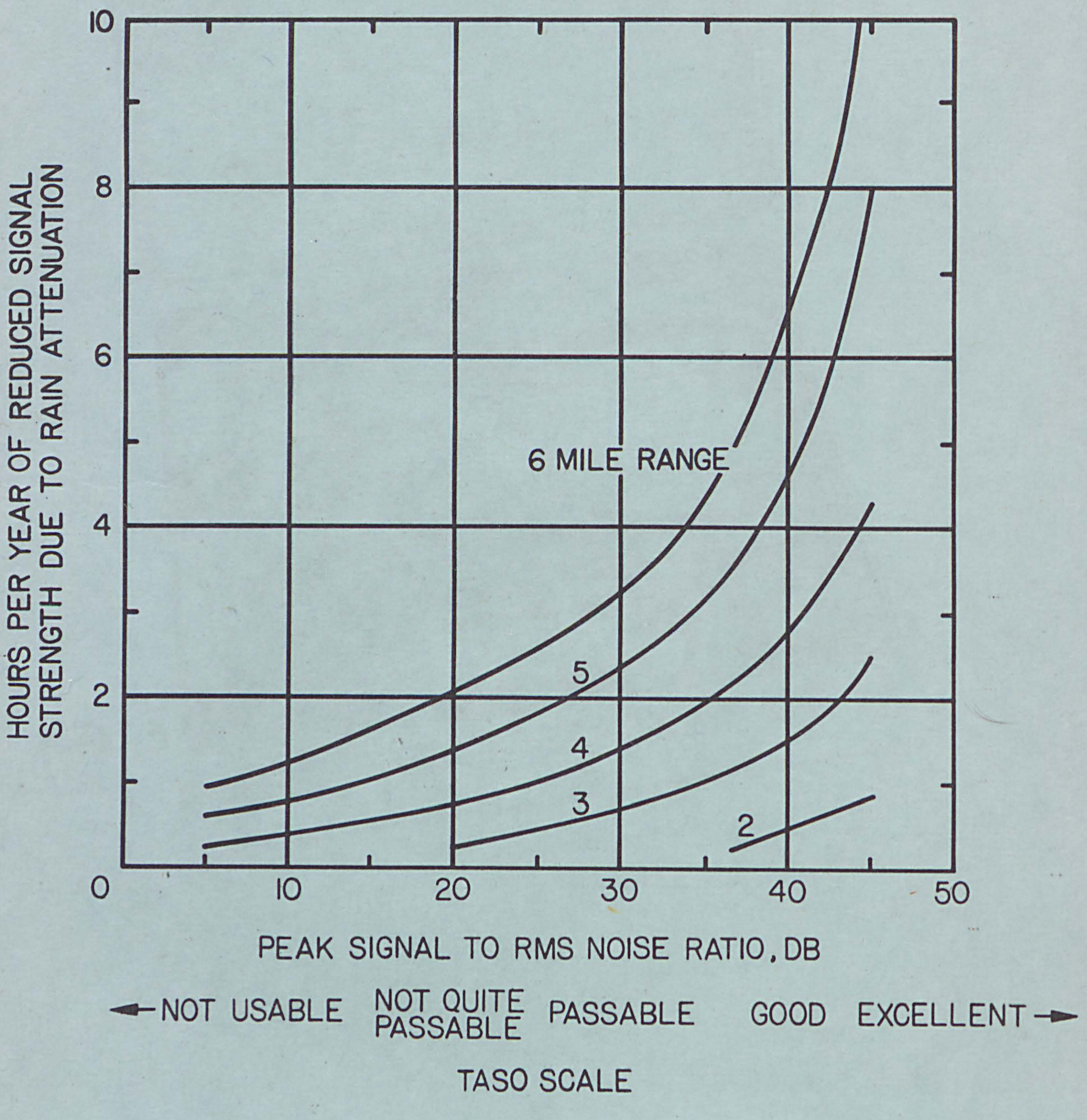


Figure 9 Inside view of AML experimental receiver

Figure 10 Subjective effect of rain on AML performance for one year in the Washington, D. C./New York City area.



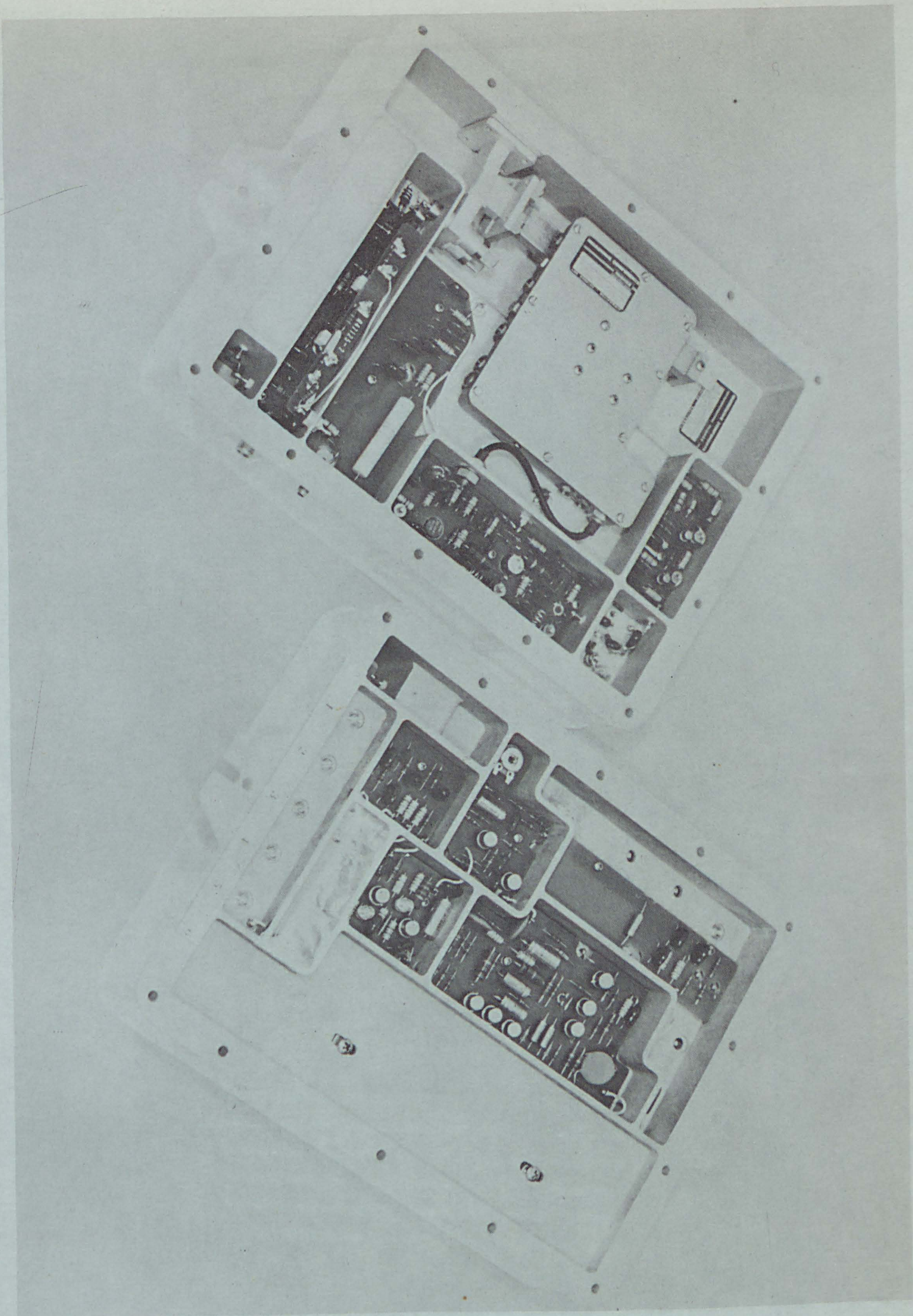


Figure 11 Inside view of the prototype AML receiver

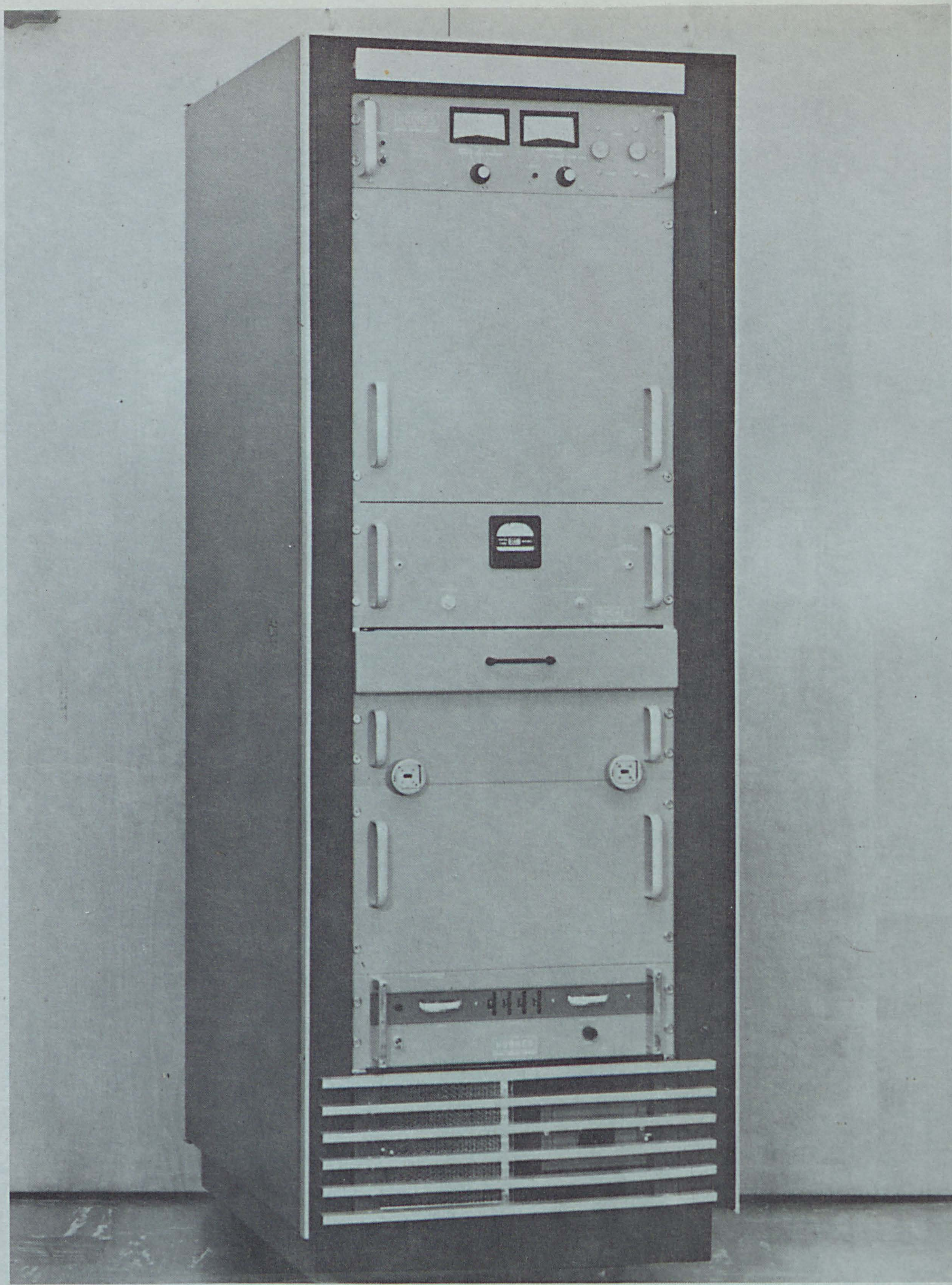
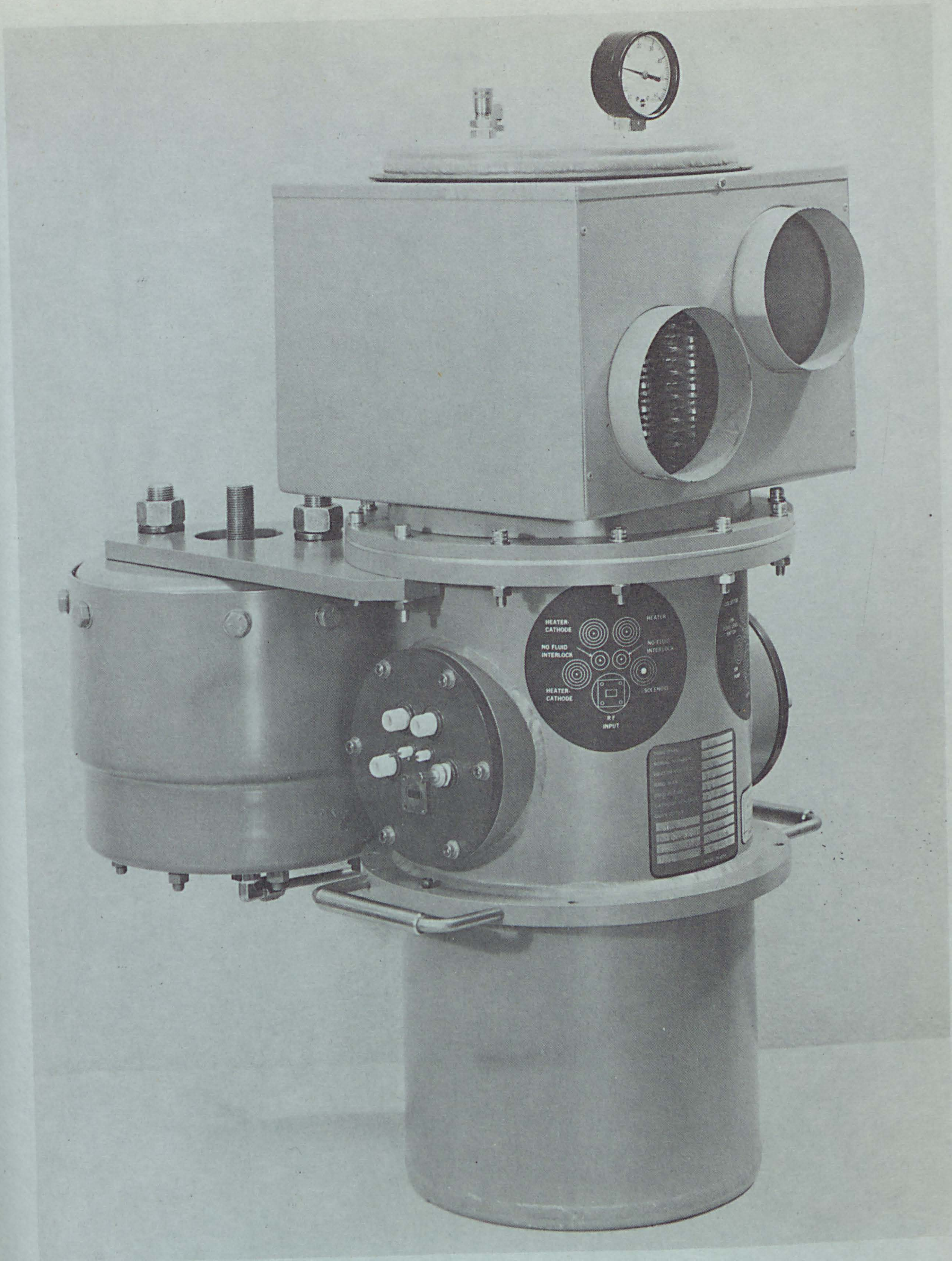


Figure 12 Prototype AML driver unit


HEATER-
CATHODE
HEATER
NO FLUID
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NO FLUID
INTERLOCK
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CATHODE
SOLENOID
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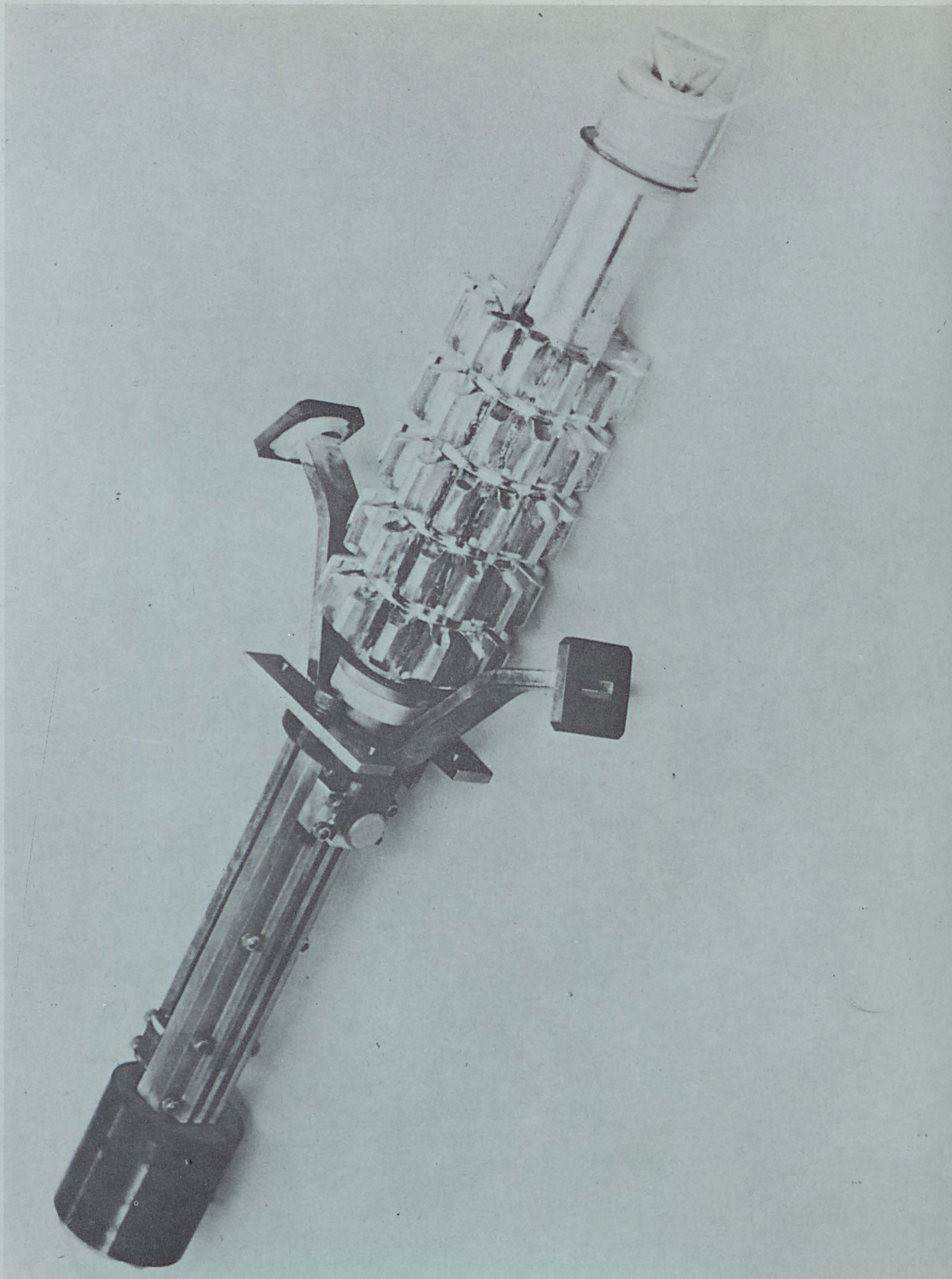

Figure 13a, b Internal views of the AML prototype TWT

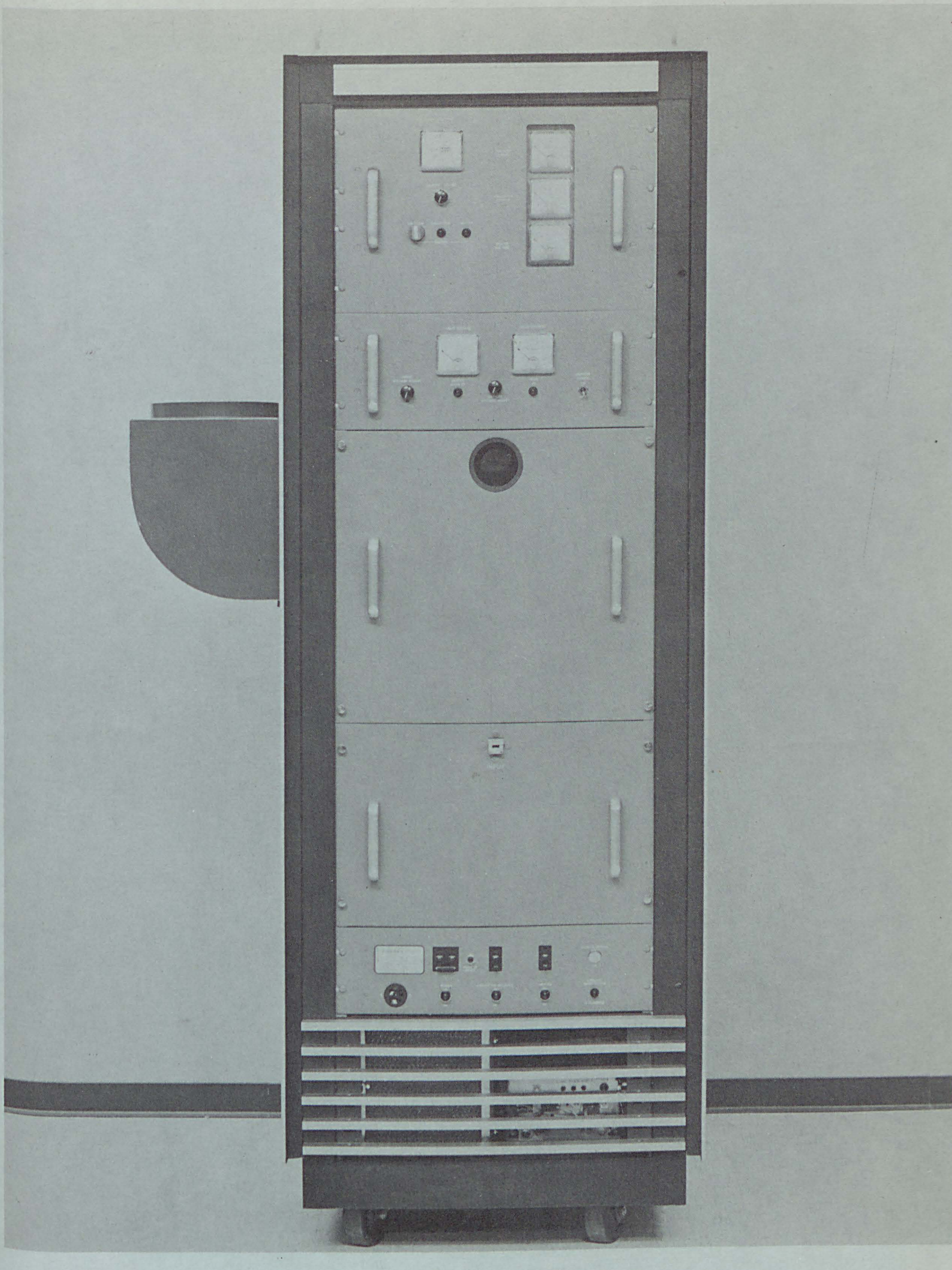

Figure 14 AML prototype transmitter power amplifier

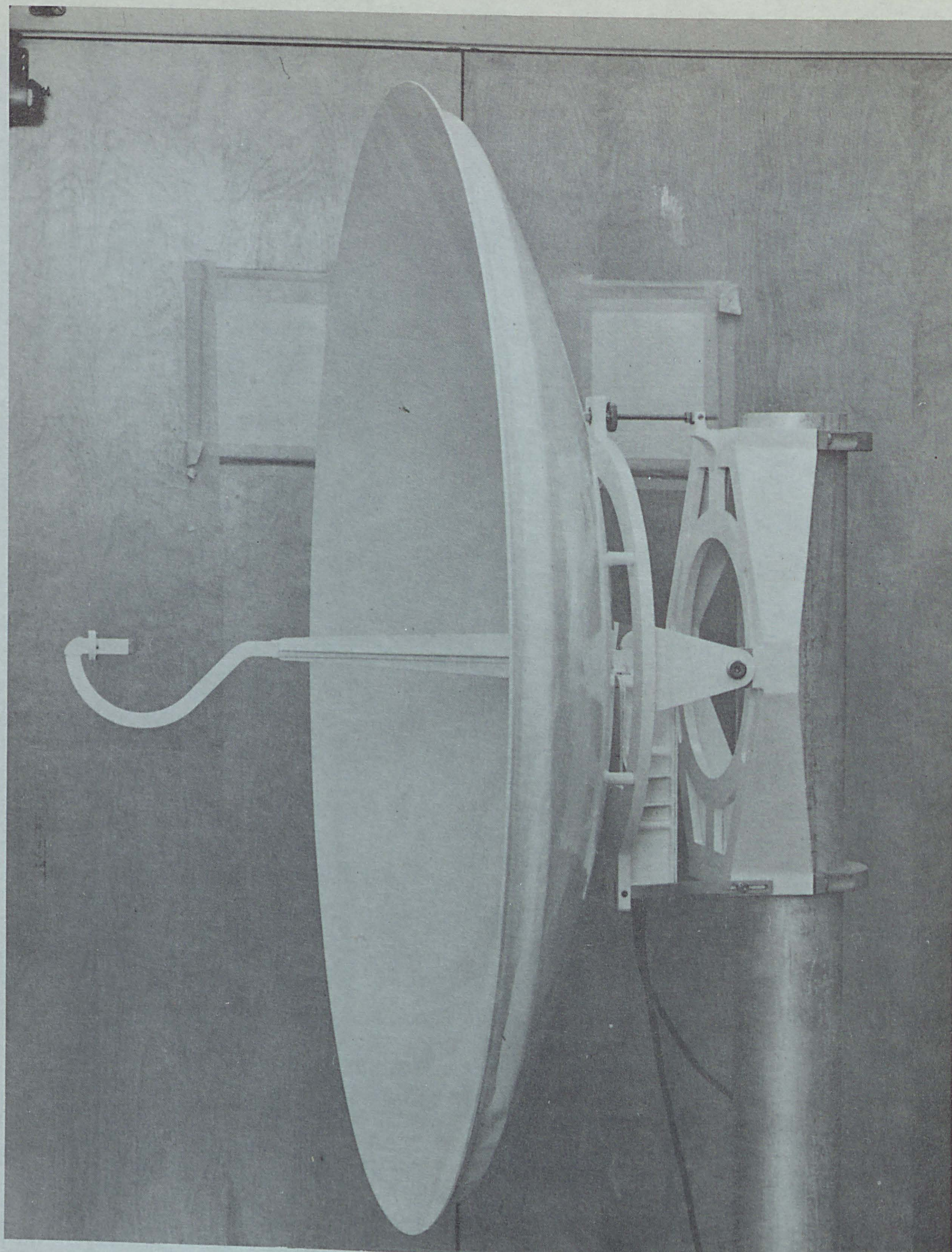

Figure 15 AML prototype receiver and receiving antenna

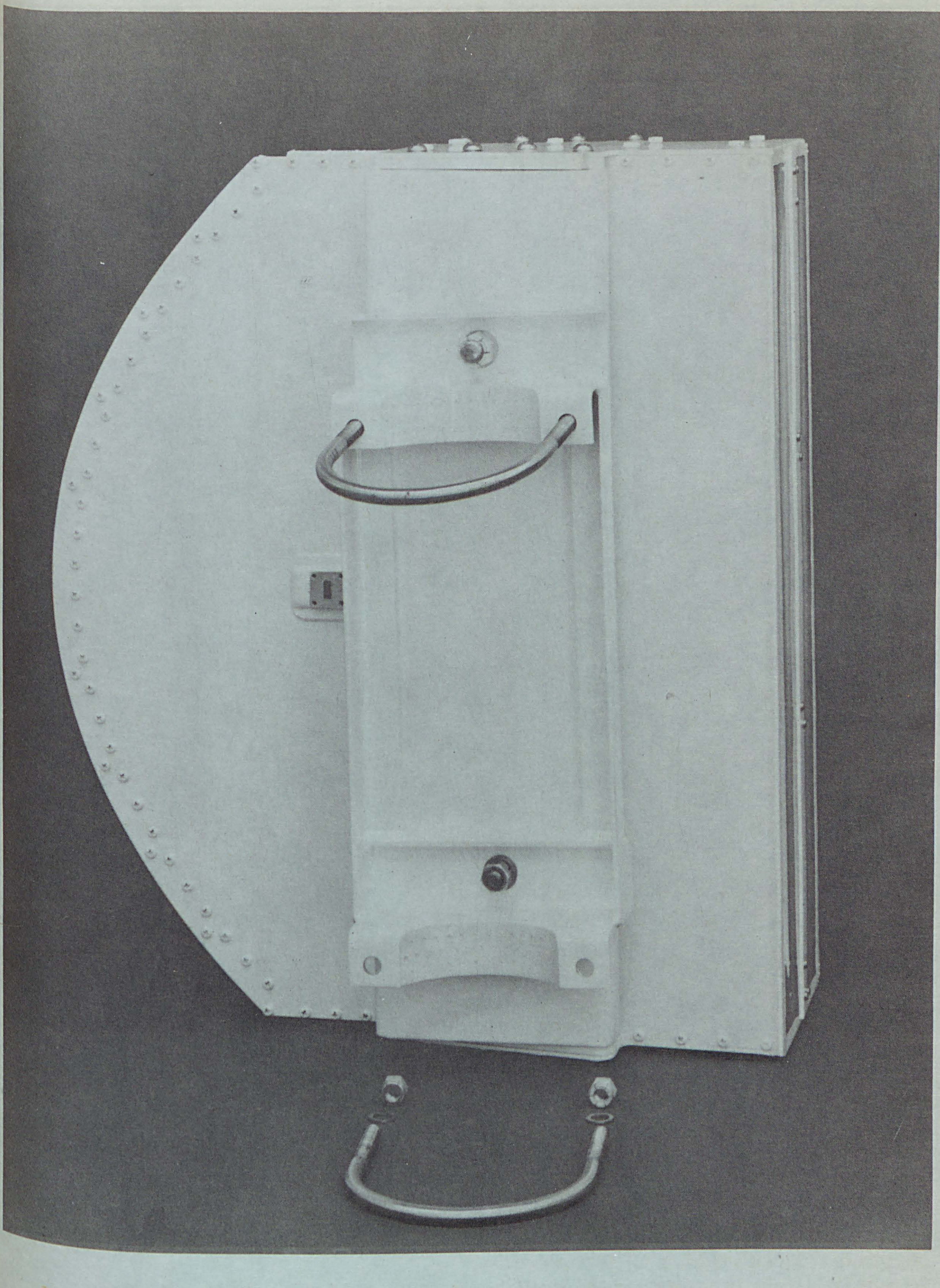

Figure 16 AML prototype transmitting antenna, side view

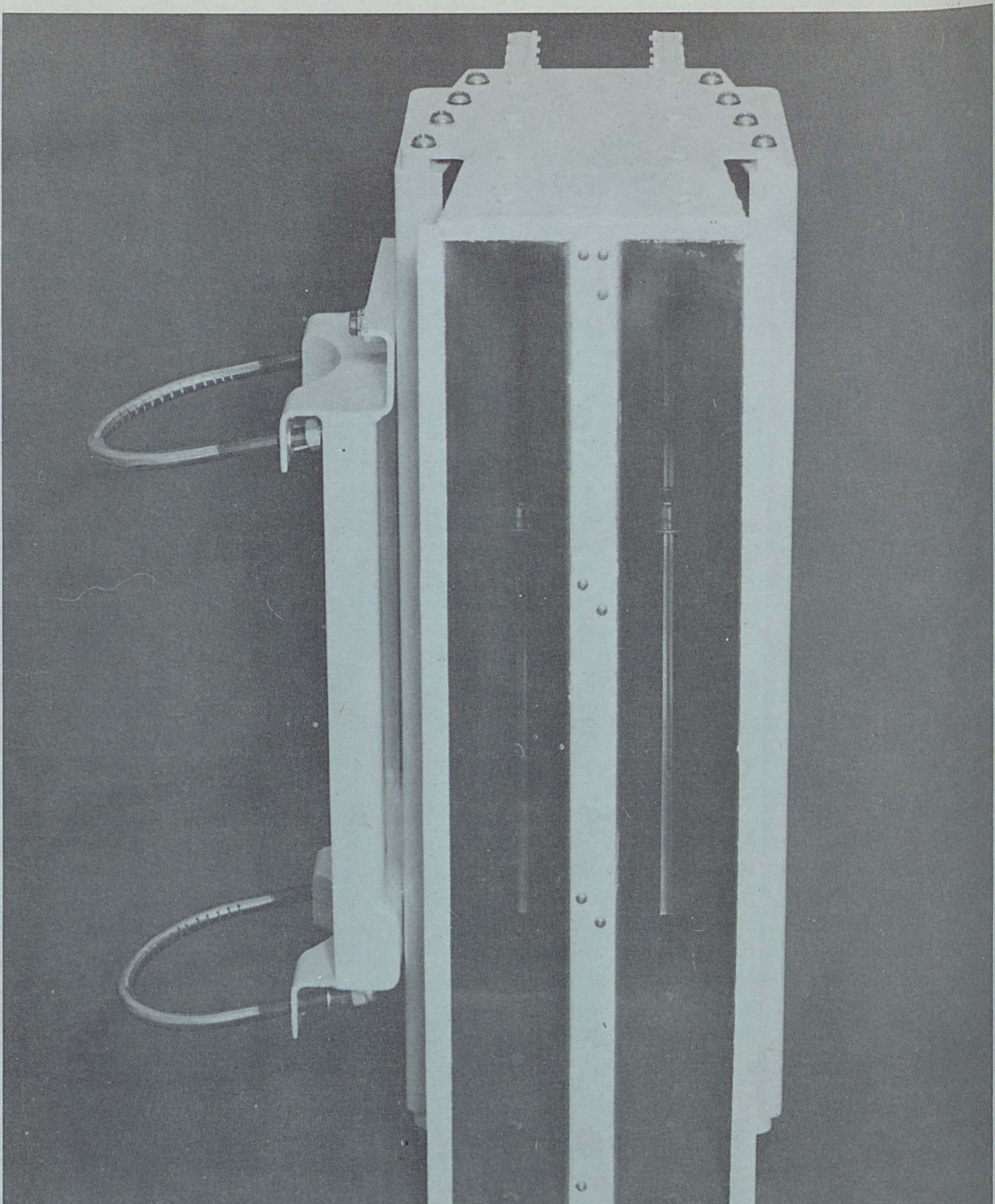

Figure 17 AML prototype transmitting antenna, front view

CHAIRMAN SCHATZEL: Thank you very much. I think this team from Hughes Aircraft Company has given us an extremely worthwhile progress report on a development that I am sure we will see a great deal more of as the years go by, the FCC willing, and I hope that they will be willing.

Due to the rather limited time we have available this morning, I am not going to be able to entertain more than perhaps two questions of Mr. Stokes or Dr. Ozaki, and then we must move on with our agenda. I believe, however, that both of these individuals will be very happy to answer any questions that you may wish to put to them privately after they have left the platform.

Are there questions now?

MR. EDWARD DAVIS (CBS Television): Your Division Director's question was uppermost in my mind. In his own terms, do you suppose you could give us a comment, just in round numbers, what the kind of comparison, let us say, between that which we might be interested in, that is, in terms of ground base equipment, microwave or standard microwave equipment as compared with this particular unit, would indicate?

I am asking, in effect, for a comment on the cost not in precise terms, but in round numbers or in comparative terms between what we now know as terms of the cost of a single microwave length?

DR. OZAKI: First of all, any number that we give our Division Direction turns out to be too high by definition.

We have looked at the relative cost of this system in terms of our extrapolation of these costs, in quantity production versus a similar type, perhaps not a multiple-channel but a microwave system that contains all 12 channels. We believe that this system is less expensive than that kind of approach.

In terms of going the full 12 channels in the systems versus having 12 single channels, I believe that there would be a marked difference in the cost.

Does that answer your question?

MR. DAVIS: You have said it is less than or comparable to?

DR. OZAKI: It is less than. It is my belief that it is less than; and, of course, here again is the question of how many do you make at one time?

MR. DAVIS: Certainly.

CHAIRMAN SCHATZEL: We have time for one more question.

MR. SIMMONS (Jerrold): With regard to the inter-modulation, do we understand that this is what we call cross-modulation; that is, modulation transferred from one channel to another? And, did if follow the theoretical law of two for one?

DR. OZAKI: This matter of inter-modulation, with respect to TV pictures, is slowly becoming more and more clear to us. The inter-modulation we are talking about does follow the two-to-one law. They are what are commonly called third order products.

CHAIRMAN SCHATZEL: Thank you very much.

(Announcements)

The next topic is truly a "bread-and-butter" topic for people in the CATV business.

The subject is TV SIGNAL PROPAGATION, and this is almost the first question we have when we consider a CATV system. We want to know what sort of signals we are getting at the head end.

The gentleman who is going to discuss this for us this morning is the Manager of the Antenna and Microwave Products Division of Scientific Atlanta, Inc., which has a wide reputation in the antenna field, as you know.

He is an engineering graduate of Mississippi State University, and has been working for the past 10 years in the field of antenna microwave. It is my pleasure to introduce Mr. Thomas D. Smith, of Scientific Atlanta, Inc.

MR. TOM D. SMITH (Scientific Atlanta, Inc.): First, I would like to express my appreciation for allowing Scientific Atlanta to participate in NCTA's Technical Sessions.

THE THEORY OF TELEVISION SIGNAL PROPAGATION

by

T. D. Smith

Introduction

Cable technicians need a knowledge of the propagation of television signals when performing signal surveys, locating head-end sites, determining sources of interfering signals, and in the designing or specifying of antenna arrays. The purpose of this paper is to review basic propagation theory with the hope it will provide better understanding of the propagation of television signals. First, this paper defines and